RI 8228

Bureau of Mines Report of Investigations/1977

Hydraulic Stimulation of a Surface Borehole for Gob Degasification

UNITED STATES DEPARTMENT OF THE INTERIOR

Report of Investigations 8228

Hydraulic Stimulation of a Surface Borehole for Gob Degasification

By S. D. Maksimovic, C. H. Elder, and Fred N. Kissell

UNITED STATES DEPARTMENT OF THE INTERIOR
Cecil D. Andrus, Secretary

BUREAU OF MINES

This publication has been cataloged as follows:

Maksimovic, S D

Hydraulic stimulation of a surface borehole for gob degasification / by S. D. Maksimovic, C. H. Elder, and Fred N. Kissell. [Washington] : Bureau of Mines, 1977.

17 p. : ill., maps, diagrams ; 26 cm. (Report of investigations • Bureau of Mines ; 8228)

Bibliography: p. 17.

1. Mine ventilation. 2. Methane. 3. Coal mines and mining • Safety measures. 4. Mine gases. I. Elder, Curtis H., joint author. II. Kissell, Fred N., joint author. III. United States. Bureau of Mines. IV. Title. V. Series: United States. Bureau of Mines. Report of investigations • Bureau of Mines ; 8228.

TN23.U7 no. 8228 622.06173

U.S. Dept. of the Int. Library

CONTENTS

ILLUSTRATIONS

HYDRAULIC STIMULATION OF A SURFACE BOREHOLE FOR GOB DEGASIFICATION

by

S. D. Maksimovic,[1] C. H. Elder,[2] and Fred N. Kissell[3]

ABSTRACT

The Bureau of Mines evaluated the hydraulic stimulation of a gob-degasification borehole to determine if this procedure would aid in degasifying a longwall panel. The stimulated borehole did not degasify the longwall panel as expected either before or after mining of the panel started. It reduced the underground methane emission only 11 pct, considerably less than the reductions effected by two unstimulated boreholes in the same panel.

Some probable reasons for the reduced methane flow from the hydraulically stimulated borehole are very low reservoir gas pressure, location of hydraulically stimulated zones within the grouted casing, a casing break caused by lateral shifting, possible vertical movement of rock strata during caving, grouting of a 4-inch pipe blocking three stimulated zones, plasticity of shales, and possible hole damage by swelling of water-sensitive minerals. The borehole was also located between two second-mined areas, which may have allowed partial degasification of the overburden and the coalbed in advance of mining. Finally, a period of 3 months is probably not long enough for the borehole to degasify the overburden before mining.

INTRODUCTION

Methane is stored under pressure in the micropores and fractures of coalbeds and is also present in adjacent strata. The rate of methane emission during coal mining may vary substantially from one mine to another. In some very gassy mines, a single section may produce several million cubic feet per day of methane (7).[4] This creates problems even with the best conventional ventilation system that can be designed, particularly in longwall mining where the superjacent strata are caved as mining progresses. When caved, these

---

[1]Mining engineer.
[2]Geologist.
[3]Physical research scientist.
All authors are with the Pittsburgh Mining and Safety Research Center, Pittsburgh, Pa.
[4]Underlined numbers in parentheses refer to items in the list of references at the end of this report.

strata emit methane in addition to that already released by the mined coal. This additional gas cannot always be removed easily by a conventional mine-ventilation system. Additional shaft installations and airway maintenance to provide greater amounts of air for methane dilution are very costly.

To aid the conventional ventilation system of some gassy mines, surface gob-degasification boreholes are drilled into the overburden in advance of mining. When the longwall face passes the holes, roof subsidence causes cracks in the overburden, and methane accumulating in these cracks flows to the borehole rather than to the mines.

Gob degasification through surface boreholes has proved to be a safe and effective method of removing large quantities of methane from the Lower Kittanning (B) coalbed (12) and from the Pocahontas No. 3 coalbed (13). It was found that some surface boreholes exhausted up to 80 pct of the methane emitted from the pillar area (8). However, other holes were not as successful, so the average methane liberation was only 45 pct.

Hydraulic stimulation is a conventional technique used to improve the productivity of gas and oil wells. More recently, hydraulic stimulation of coalbeds has yielded increases in gas flow from fivefold to twentyfold (4-5). It seems reasonable to assume that the productivity of gob-degasification boreholes might also be improved by hydraulic stimulations.

The Bureau of Mines evaluated one such hydraulic stimulation conducted by a mining company to improve the productivity of their gob-degasification boreholes. The emission from the stimulated borehole was compared with emissions from two unstimulated boreholes in the same panel. Underground methane emission was also measured.

THE STUDY AREA

Mining Plan and Equipment

The study area was located in Cambria County, Pa., in the Lower Kittanning coalbed. The block of coal, mined by retreat longwall system, was 570 feet wide, 5,150 feet long, and 52 inches thick. The block was circumscribed by a set of three panel entries (5 Left and 6 Left) on each side, and E West and F West Mains on each end. The longwall panel was the fifth to be mined between E West and F West Mains. The three entries of 5 Left and 6 Left panel were mined on 80-foot centers. All entries and cross entries were approximately 18 feet wide. Figure 1 shows the location of the study area, the portion of the longwall panel mined during the study period, and the location of boreholes 37, 38, and 39. The roof was supported by units of four 40-ton-capacity props mounted on a rigid base and topped by shielded steel beams.

A single-drum, bidirectional shearer was used to mine 52 inches of the coalbed. The mined coal moves by a face chain conveyor and is discharged at the head end onto a chain conveyor in the closest 5 Left entry. From there, the coal is discharged onto a rope-frame, 42-inch belt conveyor that dumps it into mine cars. One pass of the shearer across the face produced

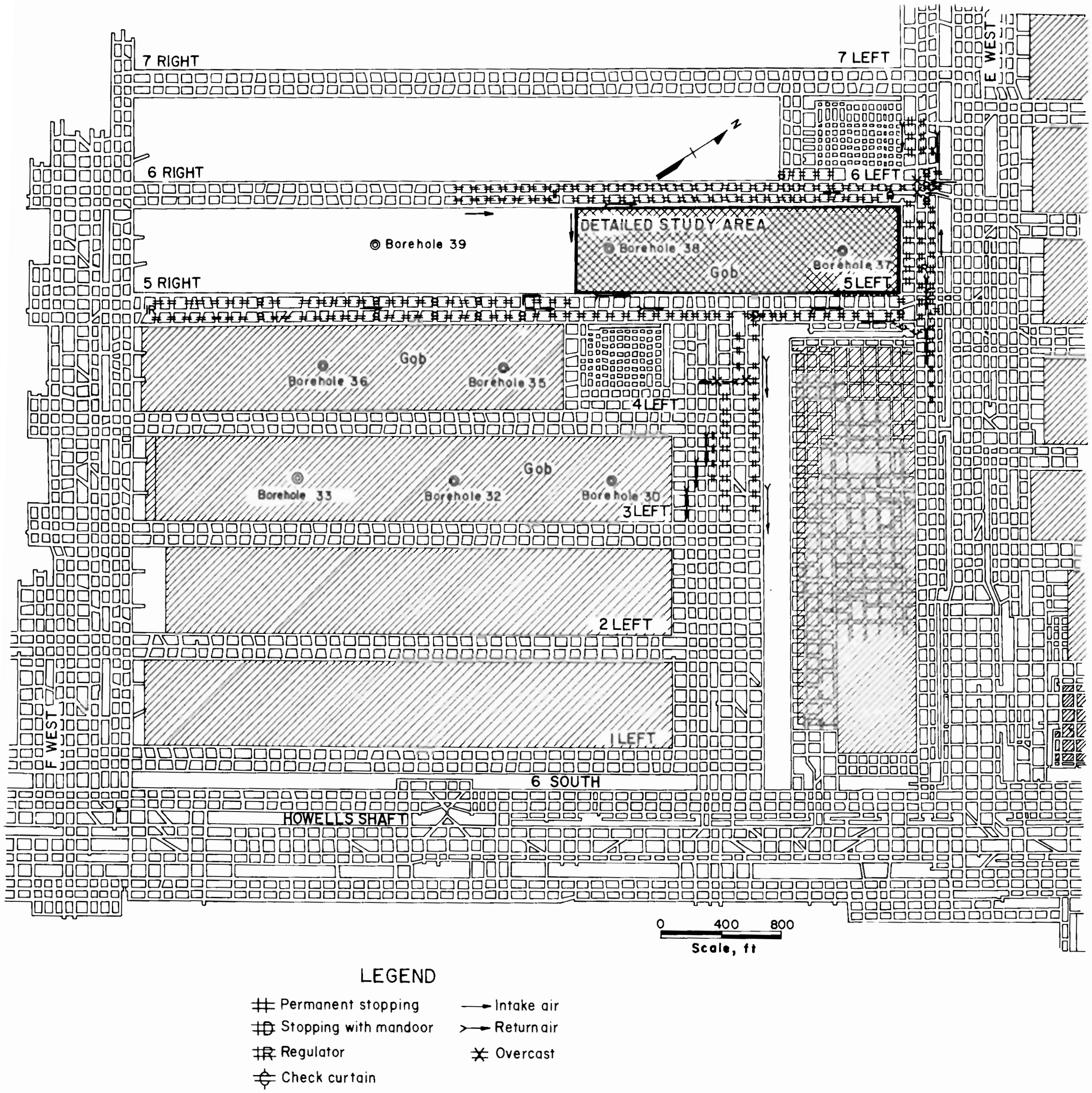

FIGURE 1. - Map of the study area.

approximately 235 tons of coal. Daily production ranged from 470 to 6,450 tons of coal during the study period.

Stratigraphy

The Lower Kittanning coalbed in Cambria County, Pa., is included in the Allegheny group of the Pennsylvania system. Here, the Allegheny group has an average thickness of approximately 250 feet. The overburden of the study area

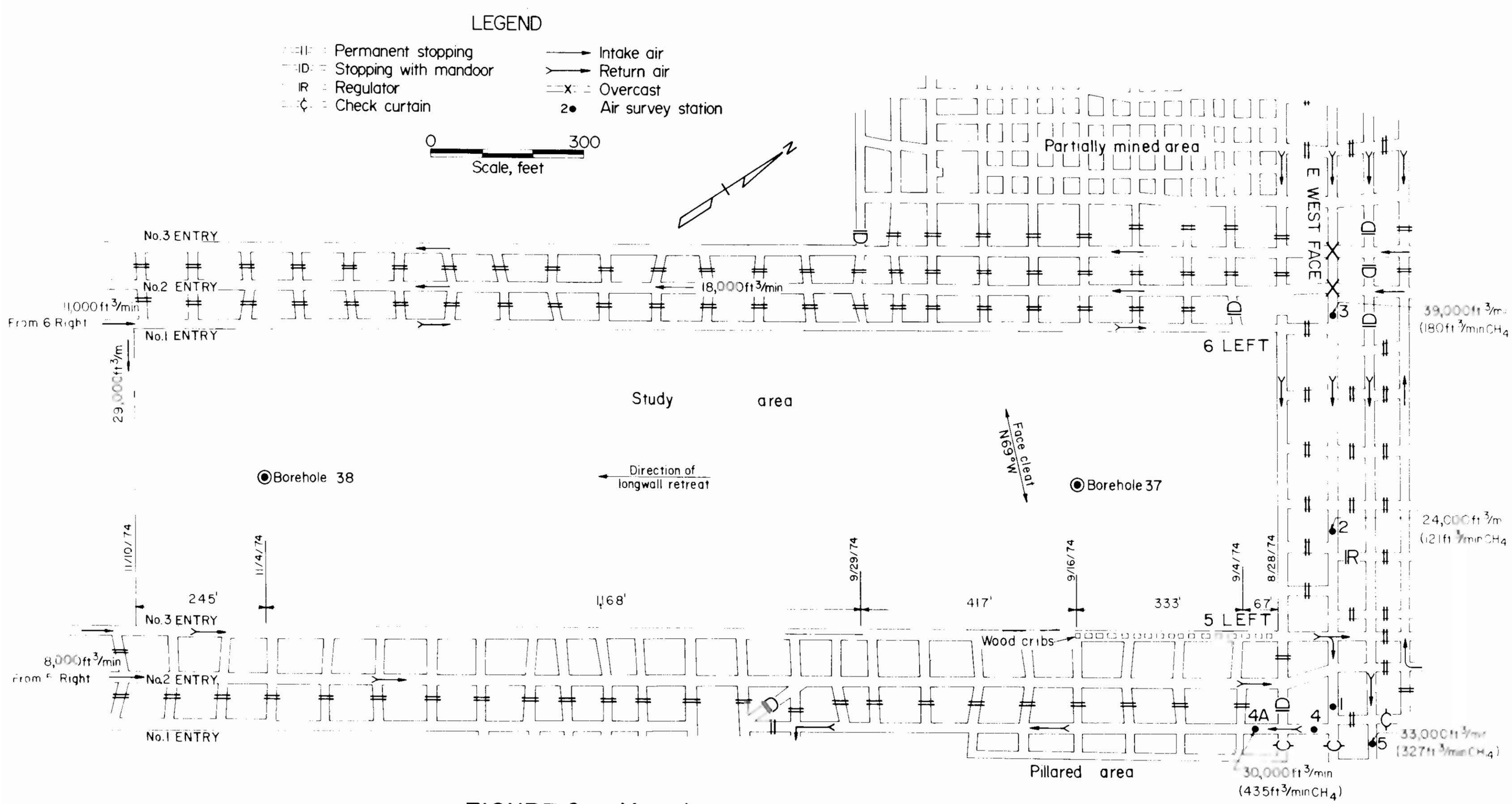

FIGURE 2. - Ventilation map with survey stations.

is about 500 feet thick. It consists mostly of carbonaceous shales, sandy shales, a few coalbeds, and some thin argillaceous limestone. The immediate roof strata are bone, coal, and 3 to 10 feet of dark to dark gray shale. The immediate 2 feet of floor is clay with coal partings. When the Lower Kittanning coalbed is mined, most of the methane comes from the fractured overburden. The amount of methane emitted directly from the coalbed into the mine working is relatively small (10). Methane is known to be present in the Upper Freeport (E), Lower Freeport (D), Upper Kittanning (C′), and Middle Kittanning (C) coalbeds, all of which overlie the mined Lower Kittanning (B) coalbed (3).

Ventilation

The study area was ventilated by two air splits (fig. 2). The primary intake air of about 29,000 ft^3/min from No. 1 entry of 6 Right panel and No. 2 entry of 6 Left panel was conducted from the tail end (6 Left) to the head end (5 Left) of the longwall system. The middle (No. 2) entry of 5 Left panel was used first as a trackless haulway for men, equipment, and supplies, and later as a return airway. A secondary regulated air intake of approximately 8,000 ft^3/min was conducted from the 5 Right panel in the middle (No. 2) entry of 5 Left panel to the head end, where it was mixed with air from the 6 Right and 6 Left panel entries mentioned previously. The first 400 feet of 5 Left entry adjacent to the longwall panel were supported with wood cribs to permit the flow of air along the right edge of the gob after caving. The airflow at the edge of the gob is controlled by opening the stoppings in cross entries between No. 2 and No. 3 entries of 5 Left panel (figs. 1-2).

UNDERGROUND MONITORING

Hand-held instrument readings of methane concentrations and air volume were taken during the study period on a weekly basis and were supplemented with readings from continuously recording methanometers. During the weekly survey, bottle samples for laboratory analysis were taken to check the two types of methanometer data. Ventilation and methane concentration were monitored from September 4, 1974, when the longwall face had been retreated 70 feet, to November 26, 1974, when the longwall face had been retreated 2,230 feet. Continuously recording instruments were normally in operation 24 hours each day. The monitoring stations, and flows of methane and air, are shown in figure 2.

VERTICAL GOB-DEGASIFICATION BOREHOLES

Three degasification boreholes were drilled from the surface into the longwall panel in advance of mining.

Stimulated Borehole 37

Borehole 37 was located in the middle of the panel 400 feet from the starting end. A 16-inch surface hole was drilled 23 feet to firm rock and cased with 14-inch-ID casing. From this point, the hole was continued 12 inches in diameter to a depth of 538 feet, 10 feet below the base of the Lower Kittanning coalbed (fig. 3).

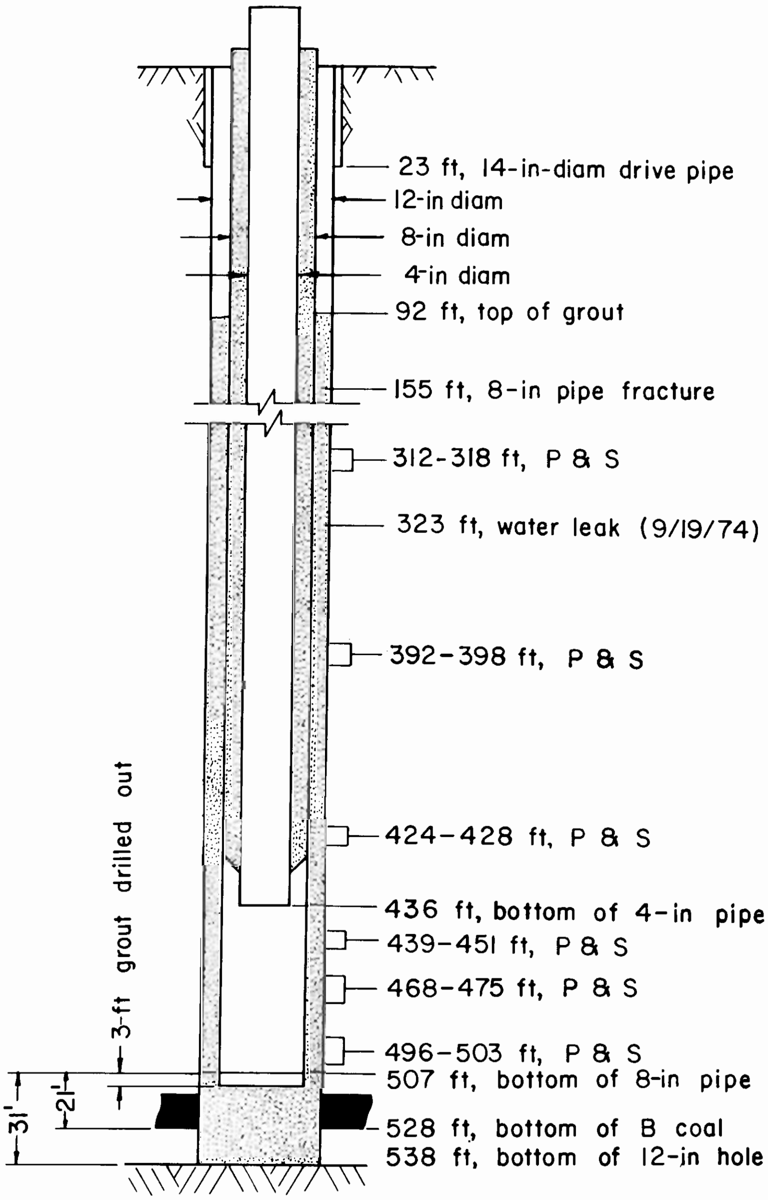

FIGURE 3. - Detail of hydraulically stimulated borehole 37 completion. (P & S indicates perforation and stimulation. Perforations were 0.45 in. in diam, two per foot.)

Before the hole was cased, lithology, density, neutron, and induction logs were run to locate the gas-bearing strata most likely to release gas into the gob (fig. 4). An 8-inch-ID steel casing with float shoe was then set 507 feet deep and grouted in place. The grout was pumped down the casing and up the annulus to within 92 feet of the surface. Type II cement with 10 pct potassium chloride was used to bind the casing securely to the predominantly shale strata. The float shoe and cement were drilled from the bottom of the borehole to facilitate methane drainage. This was done after the hole was fractured and flushed, and before the downhole pump was installed. The grouted casing was perforated in six selected gas-bearing strata (fig. 3). A total of 42 feet of casing was perforated with 84 charges spaced 2 per foot in each of the 6 zones.

The perforated zones were treated with 4,000 gallons of 7-1/2 pct hydrochloric acid (HCl) containing 2 pct potassium chloride. This treatment cleaned the perforation holes of cement to assure that the strata would break down and reduced the formation damage from cement and water invasion of the porous rock strata.

Following this, the rock strata in the perforated zones were hydraulically stimulated in stages with 20,000 gallons of gelled water. The treatment fluid contained 2 pct potassium chloride to inhibit clay swelling, 40 pounds of gelling agent (guar gum) per 1,000 gallons, 2 pounds friction reducer per 1,000 gallons, and 1/2 pound breaker per 1,000 gallons. Then 20,000 pounds of

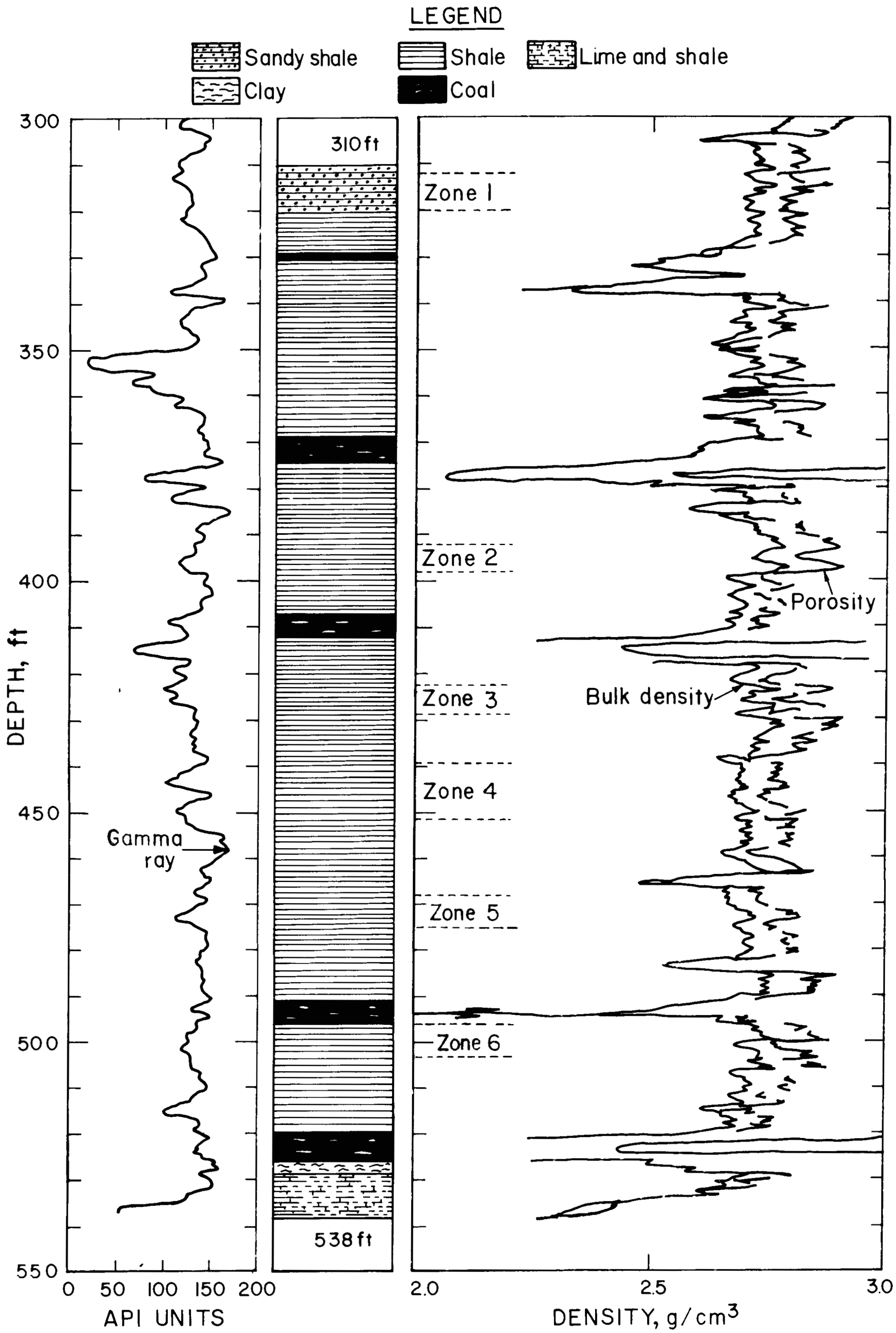

FIGURE 4. - Lithology, gamma ray, porosity, and density logs of the strata overlying the Lower Kittanning coalbed.

10- to 20-mesh sand was added to prop open the induced fractures. Rubber balls 3/4 to 7/8 inch in diameter were added in stages during the fracture treatment to assure that all perforated zones were fractured and that all of the treatment fluid was not pumped into just one perforated zone. Pumping pressures required to induce fractures averaged 2,500 psi. The treated borehole was cleaned of water and excess sand. Once in operation, the borehole was kept free of water with a downhole pump; a spark-free fan was placed on the surface to draw methane gas from the borehole.

Unstimulated Boreholes 38 and 39

Borehole 38 (fig. 5) was located in the same longwall panel as borehole 37. Distance between the two holes was 1,585 feet. A 16-foot-deep surface hole was drilled to firm rock and cased with 16 feet of 12-inch-ID casing. The hole was then drilled 10 inches in diameter to 500 feet, 1 foot below the base of the Lower Kittanning coalbed. A 6-inch-ID steel casing was set 369 feet deep and grouted in place. Grout was pumped down the annulus to fill the annular space from 366 feet to 273 feet deep, and was held in place by a seal ring and cement basket attached to the bottom of the casing. This left 110 feet of open hole below the grouted casing free for gas flow from the developing gob.

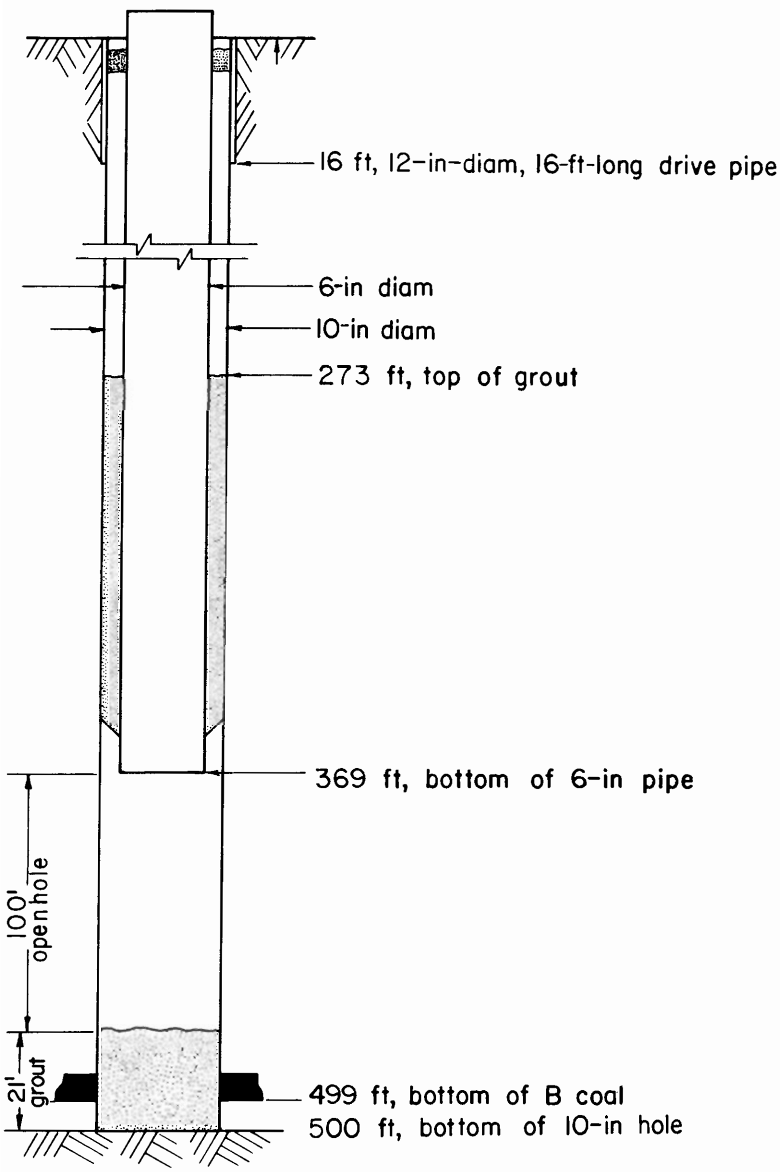

FIGURE 5. - Detail of borehole 38 completion.

Borehole 39 was located in the same panel, outside the study area, 1,600 feet from borehole 38. It was drilled and completed in a similar manner to borehole 38. The lower 120 feet of the hole was open.

RESULTS

Borehole 37

Borehole 37 was opened for flow on July 1, 1974, 11 weeks before the longwall face reached the hole. During this period, the effluent contained 88 pct methane (fig. 6) and the methane flow was 11 Mft^3/day (fig. 7). On September 16, the borehole was intersected by the retreating longwall face. Methane emission from the borehole increased as the overburden began to subside and crack. However, on the following day, lateral shifting and a casing break caused a water leak. These were fixed by grouting a 4-inch pipe inside the 8-inch-ID casing (fig. 3), but the methane production was below 100 Mft^3/day and the methane concentration in the effluent was low. An exhaust fan[5] was connected to increase the flow; however, the effluent concentration dropped closer to the upper explosive limit of 15 pct, making it necessary to shut off the fan. During the first week of October, the hole began intaking due to a loss in natural draft, so the exhaust fan was reconnected. By this time, the face was 400 feet beyond the borehole and the effluent methane concentration remained above 35 pct (fig. 6). The flow peaked at 250 Mft^3/day shortly thereafter and then began to decline steadily (fig. 7). The cumulative volume of methane from borehole 37 is shown in figure 8.

Underground Methane Emission

Underground methane emission from the longwall panel gob area during the study period started at about 170 Mft^3/day, reached its peak of 1,540 Mft^3/day 10 weeks later (fig. 7), and then declined sharply. This decline was due to two factors. First, a strike shut down the mine between November 10 and December 9. Since the methane emission from a longwall panel is closely tied to production (6, 8-9, 11), a halt in production would sharply reduce methane emission. Second, the longwall panel passed borehole 38, and much of the gas began to emerge through it.

Borehole 37 reduced underground methane emission during the study period about 11 pct, a considerably lower percentage than those obtained with the other boreholes. A survey conducted by mine personnel during April 15-May 15, 1975, showed that 17 boreholes at the mine, including boreholes 37 and 39, emitted an average of 2.5 $MMft^3$ of methane, accounting for 30 percent of the total methane emission of 8.2 $MMft^3$/day.

Boreholes 38 and 39

At the beginning of November, the longwall face intersected borehole 38. The hole was open 110 feet below the grouted casing. With an exhauster fan[6] on, methane flow started to increase and reached 650 Mft^3/day (fig. 7). During the strike, the flow declined, but when coal production resumed, the flow increased again. This demonstration of buildup and drop in methane flow is repeated whenever there is a significant change in coal extraction--after a lag-time of 2 to 6 weeks. Flow from borehole 38 dropped again when borehole 39 started production. It gradually decreased to about 60 Mft^3/day over a period of 2 months (fig. 7). The methane concentration in the effluent from borehole 38 averaged 42 pct during its production life (fig. 6).

[5] The exhaust fan was a centrifugal blower, and the vacuum was generally between 16 and 29 inches of water.

[6] The fan was similar to that used at borehole 37.

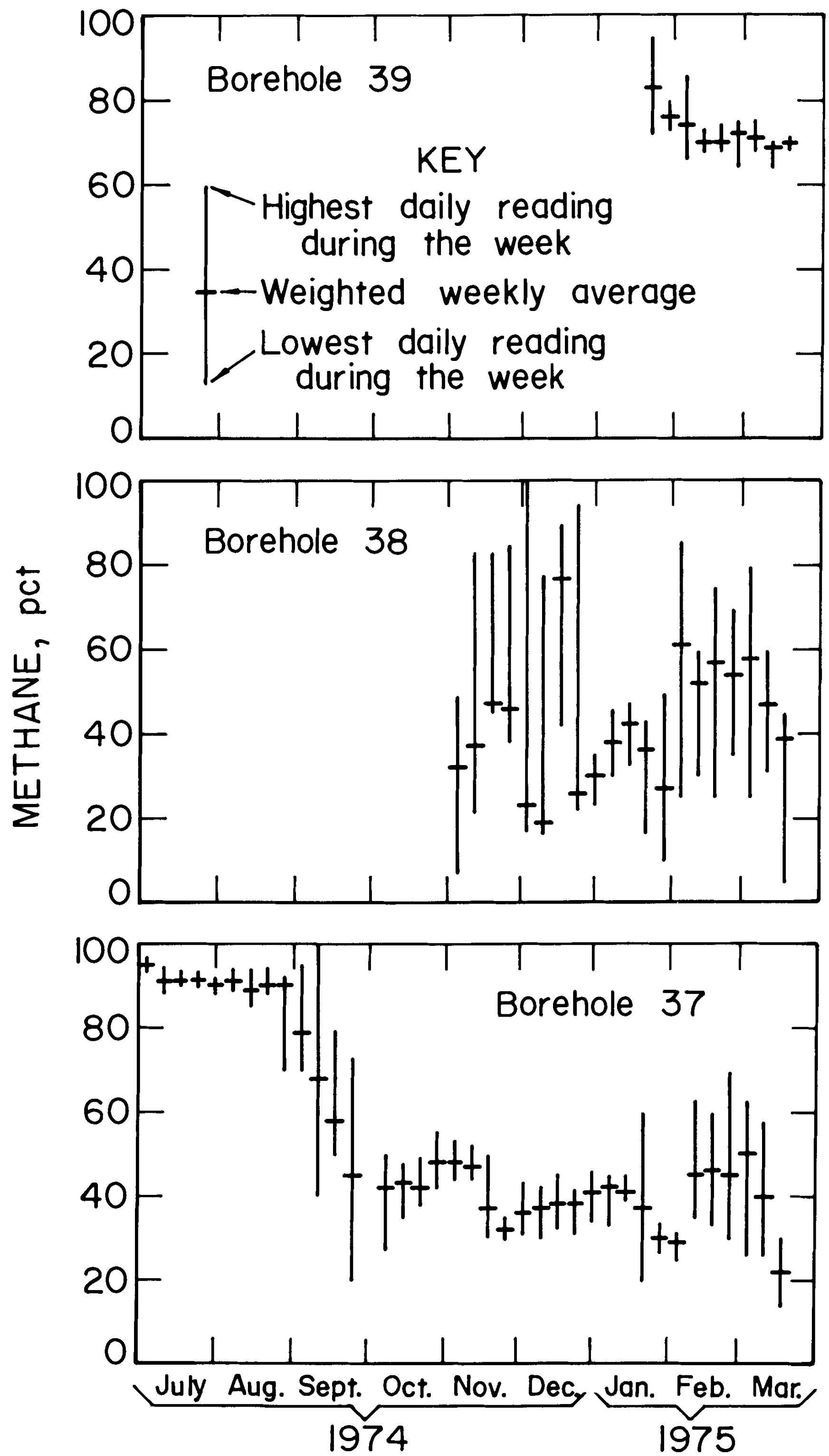

FIGURE 6. - Effluent methane concentrations for boreholes 37, 38, and 39.

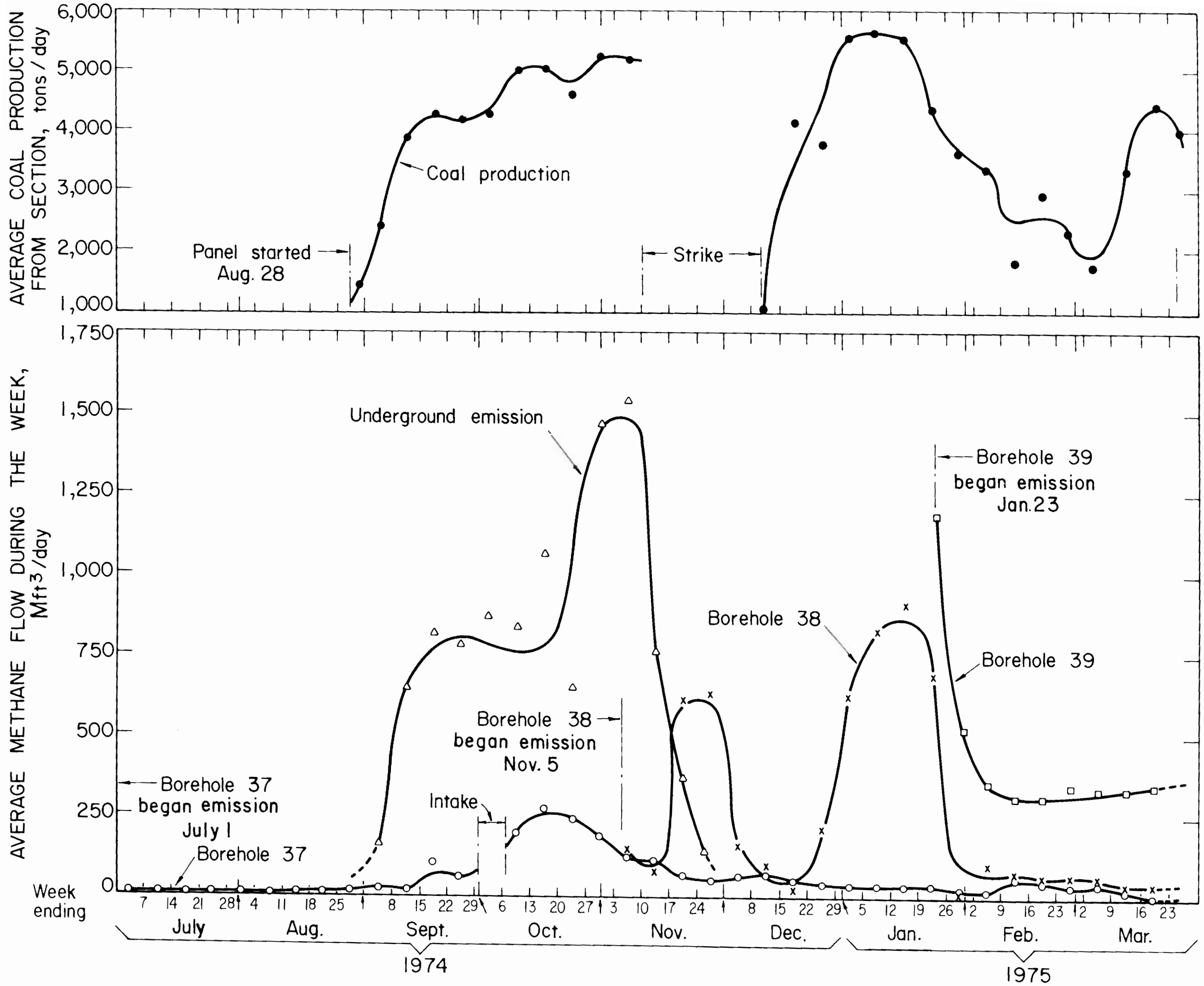

FIGURE 7. - Methane flow from section and from boreholes, and coal production from section.

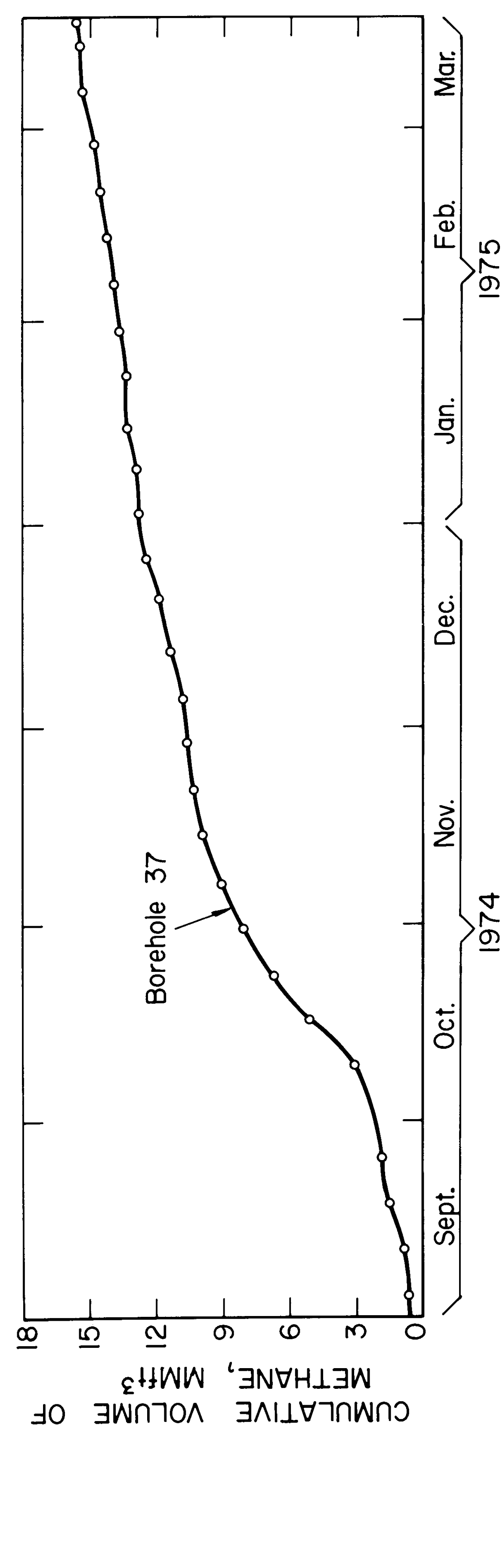

FIGURE 8. - Cumulative volume of methane from borehole 37.

Borehole 39 started methane production 2 months before mining of the panel was completed. Methane flow from this hole was initially 1,500 Mft^3/day at 93 pct concentration, but 1 week later it dropped to about 340 Mft^3/day and continued at this rate over a 7-week period (fig. 7) at a methane concentration of 71 pct (fig. 6). Borehole 39 continued to emit methane during 1975, but declined from 329 Mft^3/day in April to 187 Mft^3/day in January 1976, at a 55-pct concentration.

Cumulative methane volume for boreholes 38 and 39 is given in figure 9. Comparative cumulative methane emission underground and from boreholes is given in figure 10. While in operation and during the mining of the study section, borehole 37 yielded 15.5 $MMft^3$ of methane, borehole 38 yielded 35 $MMft^3$ of methane, and borehole 39 yielded 25 $MMft^3$ of methane. Methane flow from boreholes 37 and 39 continued after the longwall panel was completed at the end of March 1975.

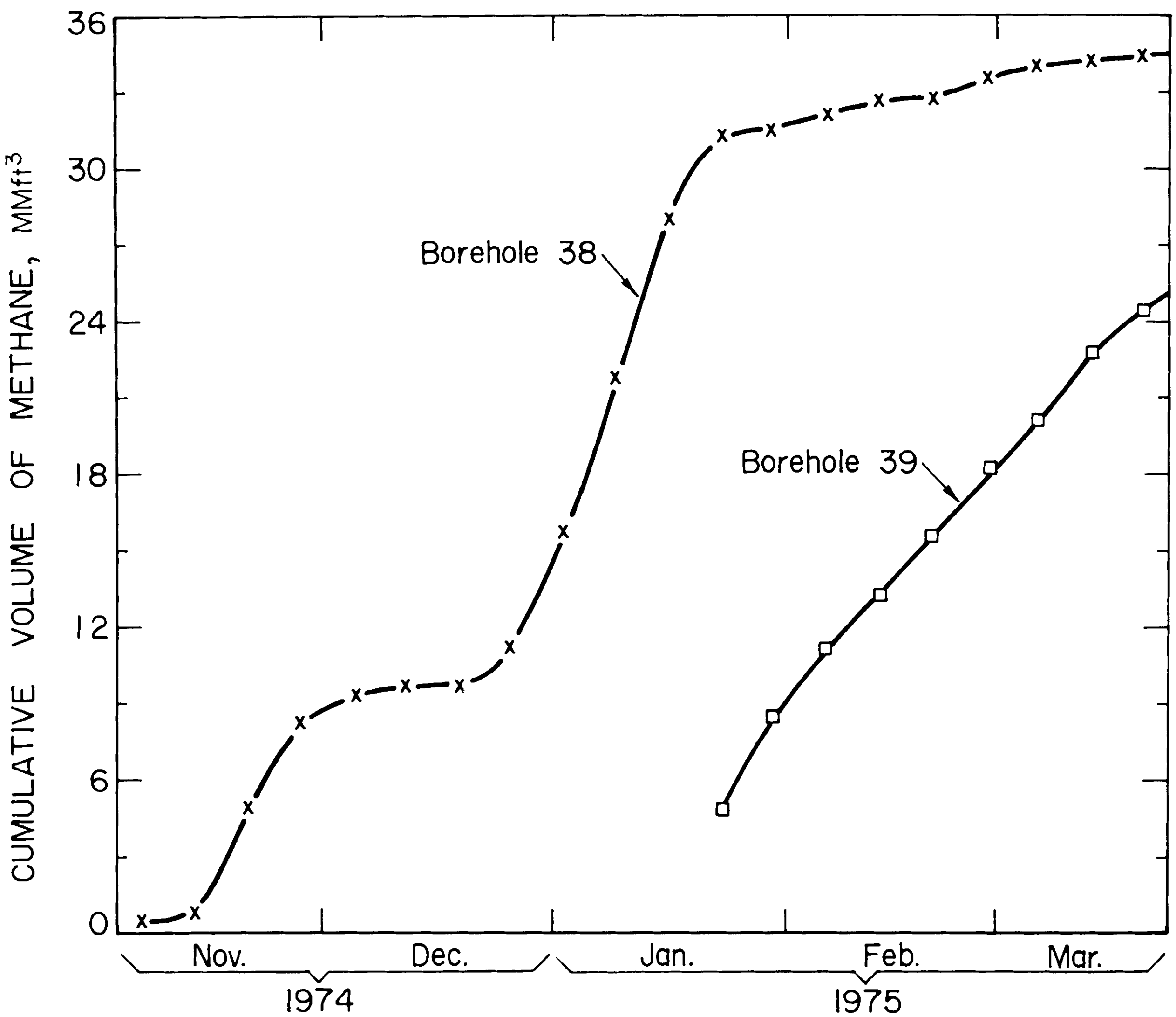

FIGURE 9. - Cumulative volume of methane from boreholes 38 and 39.

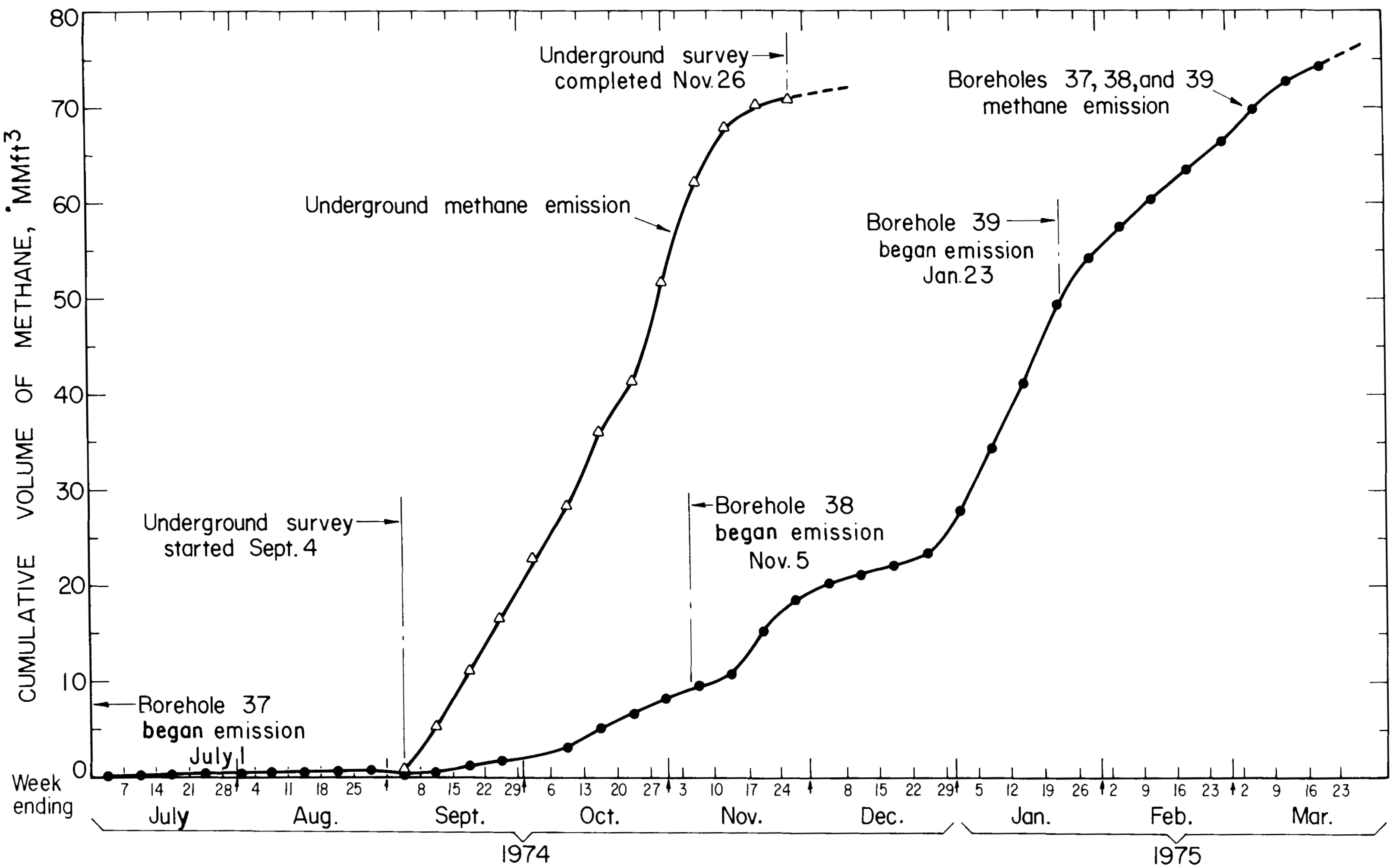

FIGURE 10. - Cumulative volume of methane from section and from boreholes 37, 38, and 39.

CONCLUSIONS

Borehole 37 did not degasify the overburden as expected. It started to relieve methane from the gob area about 1 month after the longwall-face intersection. In contrast, hole 38 started to relieve methane within 24 hours after intersection. The methane flow from borehole 37 reduced the methane emission from the gob area 11 pct during the study period, or about one-third the average 30-pct effectiveness of 17 boreholes drilled over the same coalbed.

The reduced methane flow from this hole is probably due to the following factors:

1. Borehole 37 was cased and grouted to 10 feet below the bottom of the Lower Kittanning coalbed. All six hydraulically fractured zones were located in the grouted casing. Because the gas pressures were very low, the casing perforations may have restricted gas flow. The six zones were located so no roof above any coal seam would be fractured. Hydraulic fracturing of the open hole would have provided maximum exposure of fractured strata for gas flow with a minimum chance of formation plugging. The hole was cased and grouted because it was not intended to fracture the coal seams or roof above the coal seams.

2. Lateral shifting, which broke the casing, was probably followed by vertical movement of the formation during caving. This may have caused the perforated casing and stimulated fractures to become misalined, further restricting the flow.

3. Another major gas flow restriction was caused by the casing break. To fix this, it was necessary to grout new 4-inch-ID pipe inside the 8-inch-ID casing, to a depth of 436 feet, blocking the upper three hydraulically fractured zones.

4. All of the fractured zones were in shales. Here, the extension of fractures may be limited because of formation plasticity (1), eventual hole damage, and swelling of water-sensitive minerals. Thus, methane could not flow freely from the gas-bearing strata to the fractures created by stimulation and caving.

5. Borehole 37 was located between two mined areas, one pillared and the other partially mined (figs. 1 and 2). This may have allowed partial degasification of overburden and coalbed in advance of mining. Figure 7 shows that the methane flow from the hole increased more rapidly during the first half of October when the longwall face passed from the partially mined areas. Underground methane emission followed a similar trend. At this time, a 4-inch pipe was grouted inside the 8-inch pipe and an electric pump was installed.

6. A lead time of 3 months before mining of a longwall panel appears to be insufficient for the overburden to degasify before mining. More time would allow the hole to produce more gas at the same rate. In West Germany, for the very gassy Luisenthal mine, the minimum recommended time interval between

completion of the hydrofractured holes and the beginning of mining operations in the section was 5 years (2).

7. None of the four coalbeds above the Lower Kittanning coalbed were fractured. Four fractured zones were in shale, one was in sandy shale, and, one was in coal and shale. Three of these zones were in subjacent strata of coalbeds that are normally less gassy than the coalbed above (fig. 4).

8. Gas flow from boreholes 38 and 39 was much higher than from 37. The main reason for the higher flow apparently was the lack of casing in the lower part of the holes.

RECOMMENDATIONS

A hydraulically stimulated gob-degasification borehole yielded less gas than two other unstimulated boreholes located over the same longwall panel. This experiment shows that oilfield and gasfield completion procedures applied to gob-degasification boreholes must be designed especially for that purpose.

To avoid the problems that resulted in reduced effectiveness of gob degasification when using the hydraulic stimulation procedure described in this report, a different approach should be used. We recommend the following:

1. The zone believed to be the major source of gas in the overburden should be left uncased.

2. This zone should be hydraulically stimulated.

3. After dewatering, a secondary string of casing, appropriately slotted, should be installed so that the casing is suspended from the upper part of the hole where lateral shifting and vertical separation are minimized.

4. This procedure should be instituted as early as possible, certainly more than 1 year ahead of mining, and probably as soon as plans for mining the panel have developed.

5. Foam stimulation should be considered because one-third to one-fifth the volume of fluid is used, simplifying water removal and cleanup. This alone may justify the slightly higher cost of the foam.

6. The formations considered for stimulation should be tested for swelling so that zones with an adverse mineral composition will be avoided.

REFERENCES

1. Atkinson, C. H. Rio Blanco Massive Hydraulic Fracturing Demonstration. BuMines TPR 88, 1975, 11 pp.

2. Commission of European Communities. Studies of the Influence of Geology and of the Type of Formation on the Origin, the Presence and the Control of Firedamp in the Coalbearing Strata of the Saar. Collection of Reports on Research Relating to Coal, No. 55, Luxembourg, 1974, SMRE Trans. No. 6479, 5 pp.

3. Elder, C. H. Use of Vertical Boreholes for Assisting Ventilation of Longwall Gob Areas. BuMines TPR 13, 1969, 13 pp.

4. Elder, C. H., and M. Deul. Degasification of the Mary Lee Coalbed Near Oak Grove, Jefferson County, Ala., by Vertical Borehole in Advance of Mining. BuMines RI 7968, 1974, 21 pp.

5. _____. Hydraulic Stimulation Increases Degasification Rate of Coalbeds. BuMines RI 8047, 1975, 17 pp.

6. Flügge, F. Die Methanausgasung während der Gewinnung und der Forderung. (Methane Emission During Production and Haulage). Glückauf, v. 108, May 25, 1972, pp. 425-431.

7. Ferguson, P. A. Methane Control by Boreholes. Coal Age, v. 77, No. 1, January 1972, pp. 76-78.

8. _____. Degasification of a Coal Seam--Longwall Gob Area. Paper in Methane Control in Eastern U.S. Coal Mines. Proceedings of the Symposium of the Bureau of Mines/Industry Technology Transfer Seminar, Morgantown, W. Va., May 30-31, 1973. BuMines IC 8621, 1973, pp. 58-61.

9. Joliffe, G. V. The Emission of Methane From Rapidly Advancing Coal Face. Min Engr., v. 129, February 1970, pp. 325-341.

10. McCulloch, C. M., and M. Deul. Geologic Factors Causing Roof Instability and Methane Emission Problems. The Lower Kittanning Coalbed, Cambria County, Pa. BuMines RI 7769, 1973, 25 pp.

11. Merritts, W. M., W. N. Poundstone, and B. A. Light. Removing Methane (Degasification) From the Pittsburgh Coalbed in Northern West Virginia. BuMines RI 5977, 1962, 39 pp.

12. Moore, T. D., Jr., M. Deul, and F. N. Kissell. Longwall Gob Degasification With Surface Ventilation Boreholes Above the Lower Kittanning Coalbed. BuMines RI 8195, 1976, 13 pp.

13. Moore, T. D., Jr., and M. G. Zabetakis. Effect of a Surface Borehole on Longwall Gob Degasification (Pocahontas No. 3 Coalbed). BuMines RI 7657, 1972, 9 pp.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1977-703-001/62 INT.-BU.OF MINES,PGH.,PA. 22142